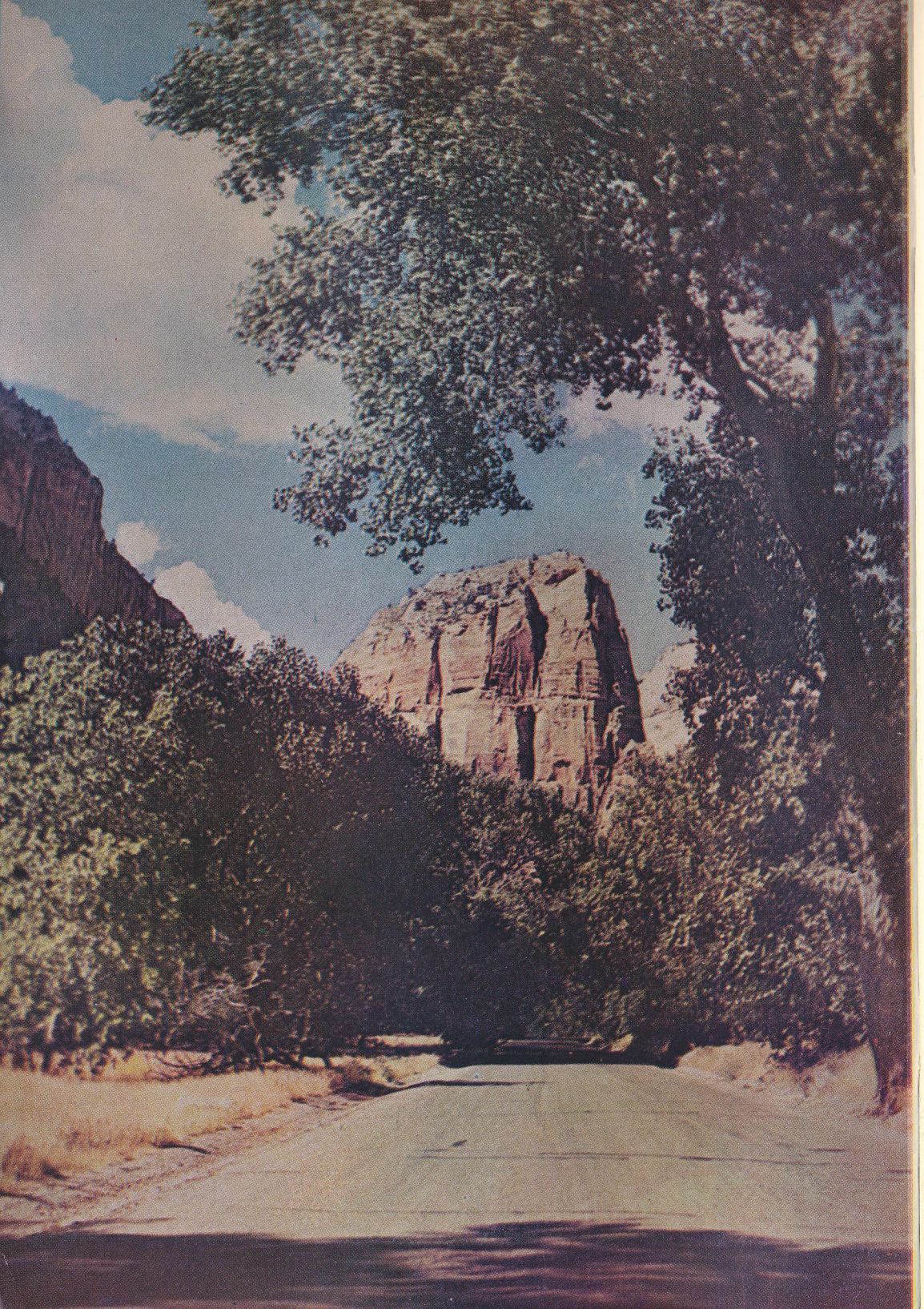
Zion National Park

A Geologic and Geographic Sketch



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Zion National Park

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THE SUPERINTENDENT

A GEOLOGIC AND GEOGRAPHIC SKETCH OF ZION NATIONAL PARK

FOREWORD

Zion Canyon which is about 8 miles long, less than half a mile wide and more than half a mile deep, is one of Nature's finest lessons in geology. Here the Virgin River has cut a cross-section through some of the most interesting of the geological formations in the earth's history. This section which is nearly 4000 feet in thickness reveals deposits of oceans, swamps, deserts, and flood plains.

Any attempt to gather from these rock layers the "geological story" is indeed fascinating; so fascinating in fact that Dr. Herbert E. Gregory has been coming to this region nearly every year since 1900 to spend several months in Southern Utah's scenic wonderlands trying to piece together the story of the ancient past.

During this period of years Dr. Gregory has become intimately acquainted with this region. He visited it first on foot or horseback with native Indians as guides. Now he flies over it in giant airplanes and photographs in a few minutes areas that required days or weeks to even reach some 40 years ago.

The first edition, printed in 1940, was so well received that the supply was soon exhausted. Thus we consider it a great privilege to here present the third edition of this geologic and geographic story as told by Dr. Gregory.

THE EDITOR

January, 1947

A GEOLOGIC AND GEOGRAPHIC SKETCH OF ZION NATIONAL PARK*

By HERBERT E. GREGORY

GEOGRAPHIC OUTLINE

Its regional setting, its erosion pattern, and its individual features combine to give Zional National Park prominence among regions of extraordinary landscapes. Here the type of scenery peculiar to the great plateaus of Southern Utah find complete expression. The long stretches of even sky line seen on approaching the park from Cedar City (northwest), Panguitch (northeast), and Grand Canyon (southeast) give an impression of extensive flat surfaces, that terminate in lines of cliffs, but viewpoints within the park reveal a ruggedness unequalled in most mountainous regions. The canyons are so narrow, so deep, and so thickly interlaced, and the edges of the strata so continuously exposed that the region seems made up of gorges, cliffs, and mesas intimately associated with a marvelous variety of minor erosion forms. The park might be considered as a mountainous country in which departures of many thousand feet from a general surface are downward rather than upward. (See Figs. 1, 2, 3, 6.)

The canyons and adjoining terracts are spectacular illustrations of erosion as developed in flat-lying rocks piled high in orderly succession, but differing in hardness and durability. The tabular forms are the edges and surfaces of hard strata from which softer layers have been stripped. The vertical lines that cross them mark the position of fractures (joints)—lines of weakness which erosion enlarges into grooves and miniature canyons. In the resulting giant stairway, cliffs in resistant rocks and slopes in weak rock constitute risers and treads that vary in steepness and height with the thickness of the strata involved. Thus, near the south entrance to Zion National Park the edge of a layer of

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hard conglomerate (pebble stone) is a vertical cliff, and its top a wide platfrom. Above this platform a long slope of shales (mudstones) broken by many benches developed in hard beds, extends upward to the great cliff faces of West Temple and the Watchman. In their regional setting these huge rock steps within the park are secondary features. They have been developed on the southern flank of the Markagunt Plateau from whose broad summit at 9,000 to 11,000 feet the country descends southward in a succession of terraces, miles in width and length, separated by cliffs hundreds of feet high, to the Virgin River at Grafton, elevation 3,650 feet. (See Figs. 1 and 3.)

The dominant feature of Zion National Park is Zion Canyon of the Virgin River, the best-known example of a deep, narrow, vertically-walled, brilliantly-colored chasm readily accessible for

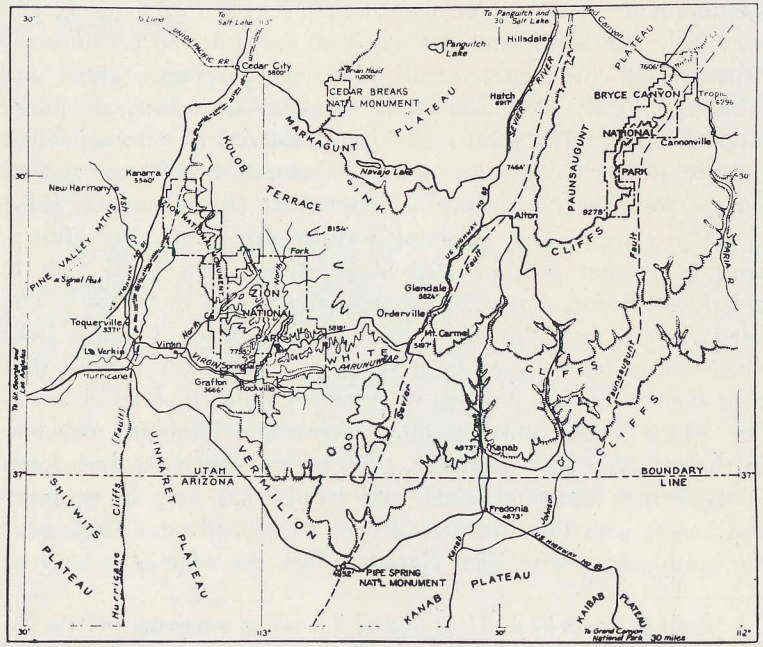

Figure 1. Sketch map of a part of southern Utah including Zion National Park. The Pink Cliffs, White Cliffs, and Vermilion Cliffs are high escarpments that mark successively lower steps cut into the south rim of Markagunt and Paunsaugunt Plateaus. The plateaus are outlined by faults.

observation. Throughout most of its course the canyon has a flat floor one quarter mile wide and bordered by walls one half mile high. At the Narrows a streamway 20 feet wide leads between walls 2000 feet high. At the Temple of Sinawava the walls are sheer and cut from a single layer of sandstone. Farther down the canyon steep lower slopes underlie the towering walls which here and there recede into alcoves and broad amphitheaters, and everywhere are decorated by slender pilasters, broad arches, and statue-like forms. All the canyon rocks are brightly colored. The majestic vertical walls of sandstone show shades of red that gradually merge upward into white. Beneath them are mauve, purple, pink, yellow, lilac shales—the most brilliantly colored rocks known. As the colors of the canyon walls are the colors of the bare rock, not of those of rock coated with soil and masked by vegetation, the tones on sunny days differ from those on cloudy days and after rains are particularly bright.

CLIMATE—VEGETATION—ANIMALS

In Zion National Park the annual rainfall ranges from 10 to 20 inches and the temperature from 10° to 105°. The winters are short and mild; the summers long and hot. Though varying greatly from year to year, month to month, and even day to day, the precipitation is so distributed as to produce two wet cycles, one in winter and early spring and one in late summer, and two dry cycles, one in late spring and early summer and one in late fall. In response to these conditions many species of plants complete their life cycle before June, and other begin their cycle in late summer and complete it in the fall. Beginning early in May the spring cycle is the time for violets, orchids, pentstemons, sego lily, and in shady nooks the columbine and monkey flower. During the excessive heat of summer day-blooming plants are largely replaced by such night-blooming species as evening primrose, four o'clock, spiderwort, and the glorious sacred datura—a veritable "moonlight garden." During the late summer cycle the roads pass through fields of asters, sunflowers, bee flowers, Indian paint brush, and sweet clover, and the cool shady nooks are made brilliant by the cardinal flower. There is little evidence of any zonal distribution of plants based on latitude or the equivalent

altitude. The range in kinds of soil, exposure to the sun, and amount of ground water is so great that indigenous plants of the Lower Sonoran, Upper Sonoran, Transition, and even Canadian zones, together with most migrating plants, find favorable habitats. On the floor of the canyon are groves of boxelder, willow, cottonwood, and ash. Above them on the talus slopes and here and there in cracks on the towering walls grow juniper, pinon, live oak, and manzanita—stunted trees and shrubs characteristic of semiarid regions. On the Kolob Terrace above the canyon walls, at an altitude of about 7,000 feet, yellow pine, white fir, Douglas fir, and aspens are the dominant species. But in favorable places these pines and firs extend to the floor of the canyon, 3,000 feet below; yuccas grow high on the rim, and in damp niches are ferns and other plants that normally prefer much colder climates. On Horse Pasture Plateau pinons and junipers characteristic of the Upper Sonoran zone grow on sunny slopes at 7,300 feet, and 1,000 feet below them, in a shady valley, are yellow pines and quaking aspens of the Transition zone.

The distribution of animal life in Zion National Park is indeed varied, for the deep narrow shaded canyons and open sunny slopes have provided habitats for animals of Sonoran, Transition and Canadian zones. Thus it seems that the desert and the plateau have been telescoped together as far as many forms of animal life are concerned. Of the approximately 150 species of birds recorded from the park there are such forms as the road-runner, water ouzel, shrike, phoebe, titmouse, kinglet, kingfisher, burrowing owl, golden eagle, Gambel's quail, Treganza's heron, warblers, hummingbirds, vireos, kingbirds, and many flycatchers. The mammals present a mixed group with such forms as deer, cougar, porcupine, ringtail cat, water shrew, antelope ground squirrel, rock squirrel, skunk, gray fox, meadow mouse, kangaroo rat, pocket gopher, and rabbits. Perhaps the forms least expected to be found in the park are the reptiles and amphibians. Among the reptiles there are the following lizards:—chuckwalla, leopard lizard, collared lizard, sonoran whiptail, desert scaly lizard, cliff uta, and Skilton's skink. Then there are the snakes:—great basin rattlesnake, gopher snake, Boyles king snake, garter snake, thimble snake, bi-colored ground snake, spotted night snake, and the rare patch-nose snake.

Amphibians recorded from the park as are follows:—tiger salamander, leopard frog, desert tree-toad, spadefoot toad, rocky mountain toad, and canyon toad. Invertebrate forms are likewise varied and abundant, but perhaps the most noted invertebrate is the Zion snail (Petrophysa zionis) which lives only on the wet walls of nearly sheer cliffs along the Narrows of the Virgin River.

HISTORY

The Basket Makers—the earliest inhabitants of the southwestern United States whose archaeologic remains are sufficient to identify a culture—are represented in Parunuweap Canyon by fragmentary textiles woven in fiber, fur and feathers. The Cliff Dwellers (Puebloans), who followed the Basket Makers, occupied several sites in Zion Canyon and built villages in the Parunuweap Canyon 7 miles above its mouth. All the dwelling sites are small, and most of them doubtless were occupied only when crops of corn, beans, and squash needed attention. They seem to be outposts of much larger settlements south and east of the Colorado River, which attained a cultural peak about 1100 A. D. and left a notable record of excellence in architecture, village organization, and the making of pottery. In Zion National Park and adjoining areas the Puebloans were followed by the Piutes—linguistic relatives of the powerful Ute tribes that once dominated Colorado, Utah, and Nevada. The Piutes have always been peaceful clans who built no permanent houses but maintained settlements in the Virgin River Valley, which they called "Pah-roos" (muddy turbulent water), and its bordering plateau lands at places favorable for hunting deer, rabbits, lizards, and insects, for gathering grass seed and pinion nuts, and for cultivating small fields of corn. The Indians of southern Utah, numbering about 2,000 in 1860, are now represented by a few families supported by the Government on reservations near St. George and Moccasin Springs.

The first white men to visit southwestern Utah and probably the first within the state, were members of the Dominquez-Escalante expedition, who at the time of the American Revolution (1776) undertook an adventurous journey from the Spanish settlements at Santa Fe, New Mexico, to those at Monterey, California. Knowing that attempts to find a direct route between

these ecclesiastical and military outposts of New Spain had been frustrated by futile efforts to cross the Colorado Canyon, Father Escalante followed trails that led northwestward through Colorado, thence westward to Utah Lake. In the lack of adequate information regarding a route to the coast, he abandoned the attempt to reach California and redirected his course southward. Passing by the sites of Beaver and Cedar City, he forded the Virgin River near La Verkin, traversed the Uinkaret, Kanab, and Kaibab Plateaus, and crossed the Glen Canyon of the Colorado at the place since known as the "Crossing of the Fathers." From the river he followed established trails back to Santa Fe.

Fifty years after Escalante's hurried trip through Utah, the region adjoining Zion National Park was explored by a company of about 16 men under the leadership of Jedediah S. Smith, one of the many fur traders whose activities make up much of the history of the West during the first half of the nineteenth century. In his search for pelts Smith left the outpost of the American Fur Co. on Great Salt Lake in August 1825 and in examining the streams along the base of the Wasatch Mountains discovered the Ashley (Sevier) River, which he followed some distance southward. Passing over the rim of the High Plateaus, he reached a southward-flowing river in the vicinity of St. George. This stream Smith named the "Adams River" in honor of President John Quincy Adams. In a report of a second expedition over this same route, in 1827, he renamed it the "Virgin River," presumably in recognition of the bravery of Thomas Virgin, a member of his party who was wounded in a fight with Indians.

Neither Escalante and the other Spaniards who followed this route nor Smith and other fur traders of his time saw Zion Canyon. These early travelers diverged little from the most feasible routes. The priests were interested in finding fields for religious propaganda; the trappers in finding "beaver country." Exploration of southern Utah resulted from plans made by the Mormon Church for the expansion of its economic, cultural, and ecclesiastical interests. Soon after the founding of "Zion" (Salt Lake City,) in 1847, scouts were sent forward across the High Plateaus and among the "southern mountains" to select sites where water and arable lands were available. Favorable reports from small settlements

founded at Toquerville and Virgin City (1858) led to systematic colonization, beginning in 1861, when "several hundred" families moved from northern Utah to lands along the Virgin River. St. George (1861-62) was founded as the capital of this new empire, dubbed "Dixie Land" in the expectation that cotton planting would become the chief industry. The search for new lands suitable for irrigation farming resulted in settlements at Grafton, Rockville, and Springdale, on the immediate border of Zion National Park, and the discovery of the canyon known to the Piutes as Ioogoon (arrow quiver; "Come out the way you come in"). Guided by friendly Indians to the mouth of this canyon (Zion Canyon), Nephi Johnson penetrated the defile in November 1858 as far as the Great White Throne and perhaps to the Narrows. This first traverse by white men of a region later to be visited by thousands seems to have aroused little interest. A "narrow floor" enclosed by walls "too high and steep to climb" was just another among the scores of picturesque canyons sunk deeply into Markagunt Plateau. Its interest lay in the chance that its floor could be used for farming. With this possibility in mind, the canyon was rather thoroughly examined in 1861 by Joseph Black, who found suitable farm sites on the flat lands in front of Zion Lodge, upstream near the site of the Grotto Campground, and in Wiley Retreat. On these lands a few settlers cultivated corn, tobacco, garden vegetables, and fruit trees, and on the canyon floor and the plateeau above they grazed cattle and sheep, until 1909, when the area was withdrawn as a national monument. An interesting episode in the canyon history was the installation of a wire conveyor to bring timber from the high canyon rims. The site of this enterprise is Cable Mountain.

The Mormon pioneers in the Virgin Valley were primarily farmers and stockmen—not artists, scientists, nor poets. Their energies were necessarily given to the absorbing task of providing the fundamentals of living. The marvelous landscapes seen from their fields and "herd grounds" were made known to the outside world by expeditions from Washington. During his second voyage down the Colorado River, in 1871-1872, Maj. John Wesley Powell, Civil War veteran and first explorer of the Grand Canyon, extended his scientific studies northwestward to the great cliffs

that rim the High Plateaus. Members of his field party traversed the Parunuweap Canyon (pah-roon-weap; water that roars) and Little Zion Canyon, which Powell called "Mukuntuweap" (mu-koon-tu-weap; straight canyon). The description of these canyons and particularly the photographs by J. K. Hillers of the Gate to Zion, the Court of the Patriarchs, and Angels Landing for the first time called attention to the features that give Zion National Park its fame. In part contemporaneously with the work of Powell, Capt. George M. Wheeler mapped areas in southern Utah. In 1872 G. K. Gilbert traversed the North Fork of the Virgin (Mukuntuweap) from a point near its head to its junction with the East Fork (Parunuweap). The miles of canyon floor, in places less than 20 feet wide between sheer walls 2,000 feet high, he named "the Narrows—the most wonderful defile it has been my fortune to behold." (See Fig. 5.)

In mapping the Zion National Park country Powell and Wheeler were followed by Maj. C. E. Dutton, who in 1880 extended the surveys to include Kolob Terace (the high plateau into which Zion Canyon is sunk) and still higher plateaus farther north. Dutton's description of the Temples and Towers of the Virgin as seen from the east end of Smithsonian Butte is a classic in geologic literature, and the accompanying sketch by W. H. Holmes is a recognized masterpiece. (See Fig. 2.)

Dutton writes:

> At our feet the surface drops down by cliff and talus 1,200 feet upon a broad and rugged plain cut by narrow canons. The slopes, the widening ledges, the bosses of projecting rock, the naked, scanty soil, display colors which are truly amazing. Chocolate, maroon, purple, lavendar magenta, with broad bands of toned white, are laid in horizontal belts, strongly contrasting with each other, and the ever-varying slope of the surface cuts across them capriciously, so that the sharply defined belts wind about like the contours of a map. From right to left across the further foreground of the picture stretches the inner canon of the Virgin . . . Across the canon, and rather more than a mile and a half beyond it, stands the central and commanding object of the picture, the West Temple, rising 4,000 feet above the river. Its glorious summit was the object we had seen an hour before, and now the matchless beauty and majesty of its vast mass is all before us. Yet it is only the central object of a mighty throng of structures wrought up to the same exalted style, and filling up the entire panorama. Right opposite us are the two principal forks of the Virgin, the Parunuweap coming from the right or east, and the Mukuntuweap or Little Zion Valley, descending towards us from the north, now called the "Virgin River of Zion Park." The Parunuweap is seen emerging on the extreme

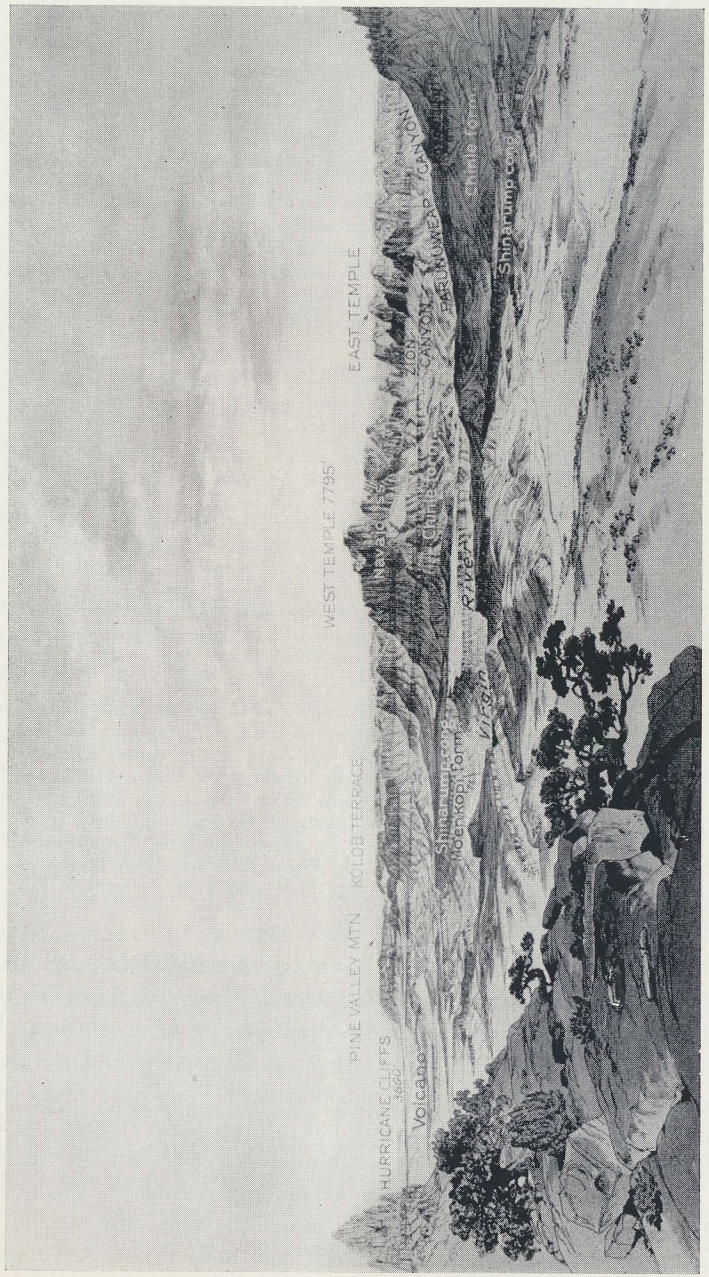

Figure 2. Panoramic sketch of the Zion Canyon region. Looking north across Virgin River from the cliffs south of Rockville. Smithsonian Butte in left foreground.

right through a stupendous gateway and chasm in the Triassic terrace, nearly 3,000 feet in depth . . . The flank of the east wall receding up the Mukuntuweap soon breaks into new forms much more impressive and wonderful. A row of towers half a mile high is quarried out of the palisade, and stands well advanced from its face. There is an eloquence to their forms which stirs the imgination with a singular power, and kindles in the mind of the dullest observer a glowing response. Just behind them, rising a thousand feet higher, is the East Temple, crowned with a cylindric dome of white sandstone; but since it is, in many respects, a repetition of the nearer West Temple, we may turn our attention to the latter. Directly in front of us a complex group of white towers, springing from a central pile, mounts upwards to the clouds. Out of their midst, and high over all, rises a dome-like mass, which dominates the entire landscape. It is almost pure white, with brilliant streaks of carmine descending its vertical walls. At the cummit it is truncated, and a flat tablet is laid upon the top, showing its edge of deep red. It is impossible to liken this object to any familiar shape, for it resembles none. Yet its shape is far from being indefinite; on the contrary, it has a definiteness and individuality which extort an exclamation of surprise when first beheld . . .

The towers which surround it are of inferior mass and altitude, but each of them is a study of fine form and architectural effect. They are white above, and change to a strong, rich red below. Dome and towers are planted upon a substructure no less admirable. Its plan is indefinite, but its profiles are perfectly systematic. A curtain wall 1,400 feet high descends vertically from the eaves of the temples and is succeeded by a steep slope of ever-widening base leading down to the esplanade courses below. The curtain wall is decorated with a lavish display of vertical moldings, and the ridges, eaves, and mitered angles are fretted with serrated cusps. This ornamentation is suggestive rather than precise, but is none the less effective . . .

Nothing can exceed the wondrous beauty of Little Zion Valley, which separates the two temples and their respective groups of towers. Nor are these the only sublime structures which look down into its depths, for similar ones are seen on either hand along its receding vista until a turn in the course carried the valley out of sight. In its proportions it is about equal to Yosemite, but in the nobility and beauty of the sculptures there is no comparison. It is Hyperion to a satyr. No wonder the fierce Mormon zealot, who named it, was reminded of the Great Zion, on which his fervid thoughts were bent—"of houses not built with hands, eternal in the heavens."

Though the grandeur and beauty of the Zion National Park region were thus pointed out by Federal surveys of 1870-80, the region was little visited during the next quarter of a century. Its remoteness from railroads and centers of population and the lack of roads by which it might be reached were handicaps not easily overcome. On the south it was cut off by the canyons of the Colorado, with no practicable crossing for more than 500 miles; on the west by the Nevada and Utah desert; and on the north and east by impassable cliffs and canyons. The only means of access even to its borders was a difficult road down Ash Creek

(See Fig. 1) to its junction with the Virgin River and along that stream to the outpost settlements of Rockville and Springdale. The way into Zion Canyon itself was so rough and tiresome that only a few adventourous travelers visited it. But the increasing demand that the region be made accessible and its unique features preserved led to its establishment as a national monument in 1909. In 1918 the locally unpopular name "Mukuntuweap" was changed to "Zion," and in 1919 the area was made a national park. The assumption of Federal control opened the way for making the region accessible and for providing accommodations for visitors.

In 1923, with the building of a 30-mile spur of the Union Pacific Railroad from the main line to Cedar City, a wagon road was graded into Zion Canyon as far as Weeping Rock, and later this road was improved and extended as a modern automobile highway as far as the Temple of Sinawava, beyond which a mile-long foot trail was constructed to the gateway of the Narrows. Access to the park from the east was provided by the Zion-Mount Carmel Highway. Begun in October 1927 and formally dedicated to travel on July 4, 1930, this road has many amazing features. The Pine Creek tunnel by which the canyon wall is penetrated is 5,607 feet long, ascends on a 5-per cent grade, and is bored just within the face of the cliff, through which opens six large windows or galleries that serve to light the tunnel and to give breath-taking views of the opposite walls. The west portal, 800 feet above the bridge across Pine Creek, is reached by a broad roadway that climbs by a 6-per cent grade on six switchbacks, attaining a length of 3½ miles in an area 1 mile long by only a quarter of a mile wide. On leaving the east portal the road crosses a high concrete bridge, and 1¼ miles farther along it passes through a second tunnel 530 feet in length, beyond which it winds about spurs and towering walls along a picturesque, sharply meandering canyon.

The superb topographic map of the park made by the Geological Survey in 1929-1932 depicts a landscape of amazing variety and marks out roads and trails leading to points on the gigantic cliffs, canyons, and plateaus, and to restful springs and brooks. Of the many trails, the East Rim and West Rim saddle-horse

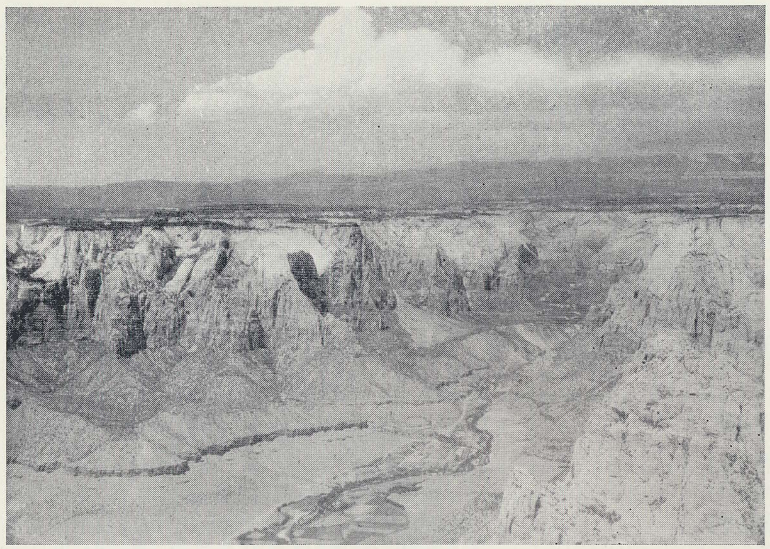

Figure 3. Gateway to Zion National Park, looking northeast along the Virgin River. Middle foreground, Virgin River Valley at the village of Springdale; middle distance, Kolob Terrace, a platform of limestone into which have been excavated Zion Canyon and other gorges walled by sandstone (White Cliffs); backround, slopes and cliffs of sandstone, shale, and coal (Gray Cliffs); on the sky line, cliffs of limestone (Pink Cliffs) of the Markaunt Plateau. The altitude of Springdale is 3,900 feet; of Markagunt Plateau 9,000 to 11,000 feet.

trails are the most spectacular. They leave the floor of the valley at the foot of the Great White Throne and climb to the rims of the canyon a half mile higher, zigzagging up talus slopes, creeping along walls by half tunnels, threading through cool, dark, slit-like canyons, following ramps cut in the faces of cliffs, crossing bridges over narrow chasms, emerging upon the dome of the upper white cliff, and finally topping out among the pines on the Kolob Terrace.

Zion Canyon seems always to have been viewed with reverence. Somehow its grandeur and beauty inspire worship that in turn brings a feeling of peace. To the pioneers of the early sixties Zion (Salt Lake) was here represented by "Little Zion," and the man-made temple at the Mormon capital by the natural temples of the canyon. In keeping with this attitude, names of religious significance bestowed by devoted visitors before the park was established have been retained and others of like purport

added. The spirit of reverence is reflected in such names as the Watchman, the Altar of Sacrifice, the Three Patriarchs, the Great White Throne, Angels Landing, the Organ, and the Temple of Sinawava.

MAKING OF ZION CANYON

Few visitors to Zion Canyon fail to ask the question, "How was the canyon formed?" Many unfamiliar with geologic processes view the deep, flat-floored vertically walled trench as a great fissure in the earth's crust formed by some "mighty upheaval." (See Fig. 3.) Others comparing it perhaps with the Yosemite Valley, which has been deepened and widened by streams of ice, think of the canyon as the work of glaciers and point to the horizontal grooves and stretches of smooth walls as evidence. Still others think of the wind as the primary or at least a sufficient contributing cause. But the horizontal layers of rock have not been broken along the line of the canyon, (those on one wall correspond layer for layer with those on the opposite wall and would join perfectly if extended across); there is no evidence of glaciation; and large-scale features resulting from aeolian action are absent. Improbable as it may seem to the layman, the evidence clearly shows that Zion Canyon is chiefly the work of the Virgin River —the stream that now flows through it. The stream is directly responsible for the depth of the canyon and, in cooperation with other agencies, for its width. The down cutting was accomplished by processes still in progress. The bed of the channel is worn by rock grains carried by the stream which thus acts as a moving ribbon of sandpaper. In its passage downstream every fragment of sand that once was part of the cubic miles of sandstone removed in excavating the canyon has aided in cutting away rock. Though the scouring process is continuous and some rock waste is carried along each day, in flood seasons the work accomplished is greatly increased. Because the tributaries flow on bare rock and thus carry the rainfall quickly to the master stream, floods follow each shower. Thus many times each year the volume and velocity of the stream are increased many fold. Huge boulders are dragged along; the banks are undercut, and the walls are scoured 10 to 40 feet above low-water level. Running on the steep

gradient of 50 to 70 feet to the mile, the Virgin River carries away from the park more than a million tons of rock waste. Even if the stream head deepened its trench but a small fraction of an inch each year, its life of hundreds of thousands of years is amply sufficient for the work accomplished. During its long life the Virgin River with its tributaries has been busy with two tasks—cutting profound gorges, and carrying to the Colorado the land waste supplied. In widening the canyons and producing other remarkable architectural features, it has played but an incidental part. At no time has the stream been as wide as Zion Canyon, probably never wider than at present, and though it has always meandered, it has not cut the embayments in the canyon walls by swinging from bank to bank. The stream has cut vertically downward, maintaining its original pattern of curves and straight stretches. At one time the canyon, where at present widest, was a gorge like the Narrows. (See Figs. 2, 4, 5.)

Figure 4. Zion Canyon looking down stream from Observation Point. On the left the east wall shows in turn the Great White Throne (foreground), Red Arch Mountain, the Twin Brothers, the East Temple, Bridge Mountain, the Watchman, and south Mountain (distance); on the right are Angels Landing, the Spearhead, Lady Mountain and one of the Patriarchs. At the Great White Throne the depth of the canyon is 2,447 feet; its width 1,200 feet. (N. P. S. photo by Grant.)

As the stream sunk its channel deeper and deeper into solid rock it left an increasingly large expanse of canyon wall exposed to the destructive action of atmospheric agencies. Frost in crevices, rain beating against the cliff faces, and acids in the air and water disintegrated and decomposed the rock, causing fragments and grains to fall to the stream below, which carried them to the mouth of the canyon and on to the Colorado River, eventually to the sea (now to Lake Mead above Boulder Dam). In this manner both walls of the originally narrow trench were worn backward.

So far, however, the walls have been eroded relatively little. Even where the canyon is widest they stand but a half mile from the river, and for long distances rise directly from the river's edge. This relation clearly shows that deepening of the trench has been much more rapid than widening. For cutting solid rock the Virgin River through Zion Canyon and farther upstream is very effective. It gathers water from a large area, flows swiftly on rock that disintegrates with exceptional ease, and its movement is not perceptibly retarded by soil or cover of vegetation. The main stream, branching headwards as Kolob Creek, Deep Creek, and Orderville Creek, is cutting so rapidly that its tributaries cannot keep pace. Because they drain small areas and flow only in response to showers, many branches are unable to cut channels as deep as the perennial master stream. From their mouths high on the canyon walls they descend from time to time as waterfalls. Like the Virgin itself these tributaries have done little to give the canyon its present form. Many of them leap from the rim barely wetting the walls behind them and scour their channels only in the short courses across the canyon floor. Scores of them after falling merely spread out as thin sheets of water that follow no definite runways. At first sight the alcoves in the canyon walls might seem to be the work of the streams from the plateau above, but the size and position of these re-entrants are not closely related to drainage areas tributary to them. Some fairly large side streams enter the canyon at places where the wall is but slightly indented. The evidence is clear that the canyon alcoves are the work of rain that falls directly into them and of underground water that seeps out through their walls. The process is sapping and undermining rather than excavation. The cliff walls of sandstone are undercut by the removal of soft shales beneath, and

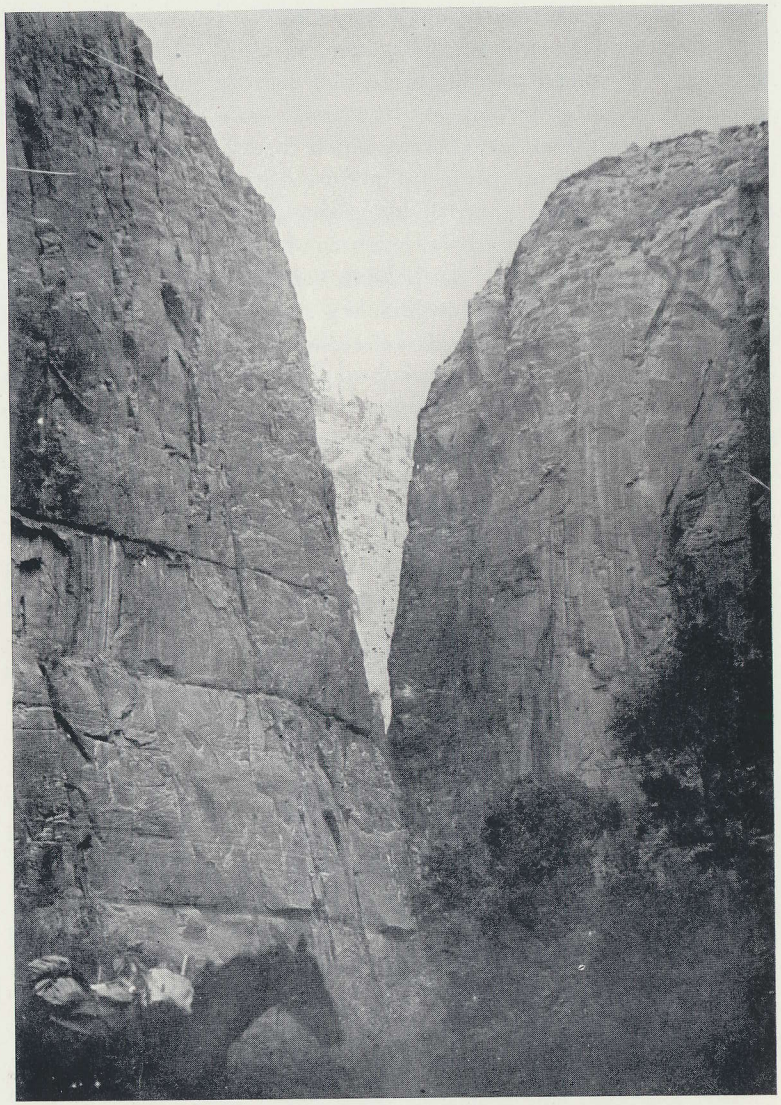

Figure 5. The Narrows just above the Temple of Sinawava. Through this defile, 2,000 feet deep and 20 by 50 feet wide, passes the Virgin River, the largest tributary to the Colorado in southern Utah.

in response to gravity fragments fall off. The walls retreat and the rim develops curves and crenulations chiefly in consequence of erosion at their bases. Thus at Wiley Retreat, the Grotto, Weeping Rock, and other prominent alcoves part of the rain water that falls on the upland passes downward through porous rock until it reaches impervious beds and finally reaches the surface as springs and seeps. On emerging, these underground waters carve horizontal grooves in the canyon walls, leaving overhanging cliffs above and a slope below. Into the slope perennial streams from the spring are cutting channels that lead to the Virgin River. This method of erosion, in progress for thousands of years, is plainly in evidence today. The "spring line" in Zion Canyon is a conspicuous feature.

In widening Zion Canyon and carving its architectural features, the work of the atmosphere and of ground water is greatly facilitated by the composition and structure of the sandstone that forms its walls. The weak cement that holds together the rounded grains of quartz is readily dissolved by rain that wets the walls and by water that seeps through the rock, thus loosening the tiny particles and permitting them to fall or to be swept from the cliff face by showers or by wind. The sandstone is reduced to sand, easily removed by streams. Features even more favorable for erosion are the cracks (joints) that traverse the canyon walls. Combined with the bedding planes—horizontal, oblique, and curved—these cracks determine the shape of the irregular chunks and huge slabs detached from the towering cliffs by frost, rain, tree roots, and ground water. Blocks embedded in the cliffs, blocks surrounded by open joints, blocks partly detached, blocks that rest precariously on some temporary support, and blocks that have fallen to the talus below indicate steps in the retreat of the canyon walls. That the process is continuous is shown by the scars on the wall, some almost obliterated, some considerably weathered, and others quite fresh. Each year many new blocks are pried off.

On some of the joint cracks slipping has taken place. The joint plane has become a "fault"—a plane of fracture along which the rock on one side has been raised higher than that on the other. Most of the faults in Zion National Park show a vertical displacement of a few inches or a few feet. Near the east

entrance to the park a fault measures 20 feet; in Wild Cat Canyon, 105 feet; and east of Cougar Mountain, 210 feet.

The joint cracks so prominently displayed on the walls of Zion Canyon are not local features. They represent thousands of cracks that cut almost vertically through the rocks of the entire park. Along these cracks, especially where they are closely spaced and where faulting has occurred, the rock is broken, even shattered, and therefore readily eroded. Taking advantage of this condition, many streams have carved their valleys along lines of pronounced jointing. This guidance of streams by structures is clearly shown on the Zion National Park topographic map by the straight, parallel tributaries to the Parunuweap, Pine Creek, Orderville Gulch, the upper Virgin, and Wildcat Creek (a tributary to North Creek), developed along joints and faults trending north-northwest. The position of many alcoves and amphitheaters and the trend of many cliffs likewise reflect the control exercised by planes of weakness. Though West Temple, East Temple, and a

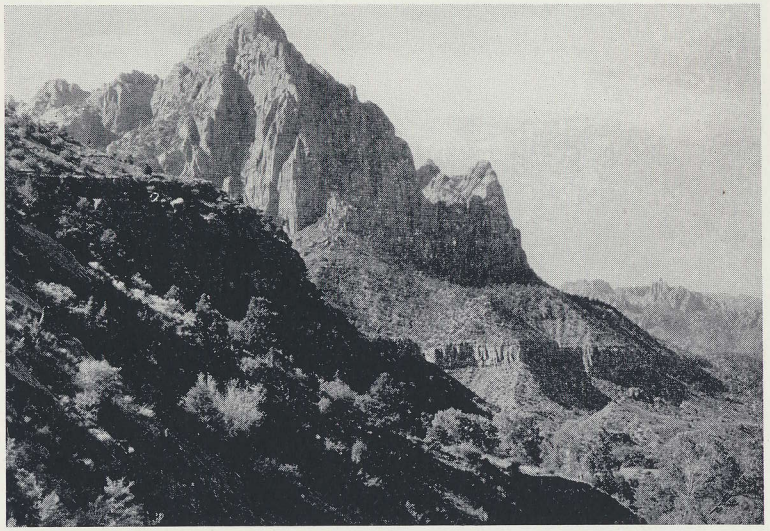

Figure 6. The Watchman, one of the many gigantic buttes in Zion National Park; rises 2,600 feet above the Virgin River at its base. Navajo sandstone at the top, below it in turn the Kayenta and Wingate (covered by talus), and the Chinle, including the "big ledge", and the variegated beds that contain petrified wood. South Mountain and Eagle Crags in left distance, beyond the Parunuweap. N. P. S. photo by Grant)

few other lofty masses are capped by limestone—undissected remnants of the Kolob Terrace—and are thus protected from erosion, most of the "towers and temples of the Virgin"—such magnificent structures as the Watchman, Mountain of the Sun, Spearhead, Castle Dome, and Guardian Angel—are sculptured blocks of relatively unfractured rock that stand between zones of jointing. They owe their individuality to the headward growth of canyons in the fractured rock that surrounds them. In fact to a very large degree the sculpture of the park was predetermined by a network of joints and faults.

Downcutting and undermining of canyons are vigorously in process today and doubtless will continue for a long time. The bed of the chief tributaries to the Virgin could be sunk 1000 feet deeper and still have slopes sufficient to carry water to the Colorado River and on to the sea (now Lake Mead). Also the rock masses remaining between canyons are enormous. In other words, the scenery of Zion National Park is geologically young; its gigantic features mark but an early stage in the erosion of the lofty Markagunt Plateau. It has been developed during the few million years that make up the last chapter in a billion years of earth history. If continued without interruption, erosion will convert the present rugged landscape into plains near sea level.

This explanatory description of the features of Zion National Park and of the processes active in making them leaves unanswered the question, How did Zion Canyon originate? Why has this particular region so many profound canyons, lofty mesas, and vertical cliffs? The complete answer involves a knowledge of a long train of events in earth history and of forces and processes as yet not fully understood. In brief, the answer is, the rise of the land with respect to sea level. At a time long past, estimated as 13,000,000 years ago, all of southern Utah and adjoining regions began to rise. This upward movement, continued slowly and intermittently until the lands once near sea level attained an altitude exceeding 10,000 feet. This regional uplift introduced a long period of time during which the conditions have been favorable for erosion. On the original lowland, streams did little work. They flowed in broad shallow valleys of gentle gradient like those on the plateaus of Cedar Breaks National Monument and Bryce Canyon National Park. In consequence of the uplift, the paths

of the streams were steepened and the streams became powerful agents of erosion. Their accelerated speed permitted them to cut trenches in solid rock and as the land rose progressively higher, to develop their trenches into the present profound canyons.

During the great uplift that brought the former low-lying lands of the Zion National Park region to a position two miles above sea level and gave the streams their power to erode, the beds of rock were broken into earth blocks many miles in length and width. One of these enormous blocks, the Markagunt fault block, includes Zion National Park. (See Fig. 1.) Its western border is the Hurricane fault which broke the beds of sandstone and limestone and raised the part on the east 1000 to 6000 feet above the part on the west. The escarpment thus formed, now much reduced by erosion, is the Hurricane Cliffs, a wall extending south from Cedar City and crossed by the Zion National Park road near La Verkin. The eastern border of the block is the Sevier fault along which, as along the Hurricane fault, the strata on the east was raised. In Parunuweap (Long) Valley south of Glendale the fault is marked by a red wall. At Mr. Carmel the limestone that caps Elkheart Cliffs stands 2000 feet above the same bed in the Virgin River below. The Markagunt block is tilted eastward; the strata descend across the park on a gradient of one to two per cent.

STORY OF THE ROCKS

Zion National Park is not only a region of scenic grandeur; a large part of geologic history is revealed in its canyon walls. Just as Grand Canyon is the best-known record of ancient geologic history, and Bryce Canyon reveals much of late geologic history, Zion Canyon records most clearly the events of middle (Mesozoic) geologic time. The story of Zion begins where that of Grand Canyon ends, and ends where that of Bryce begins. In the 16,000 feet of sedimentary rocks exposed in these three national parks are incorporated the records of a thousand million years. (See Fig. 7.)

A study of these rocks shows that the region including Zion National Park has witnessed many changes in landscape and climate. At times it was covered by the sea, at other times broad rivers traversed its surface, and at still other times it was swept by desert winds. Most of the rocks were laid down by water as gravel, sand, mud, and limy ooze. These have been consolidated into conglomerates, sandstones, shales, and limestones by the weight of layers above them and by the lime, silica, and iron that cemented their grains. Embedded in the rocks are fossil sea shells, fish, trees, snails, and the bones and tracks of land animals that sought their food in flood plains, in forests, or among sand dunes. The most conspicuous remains are those of dinosaurs—huge reptiles that so dominated the life of their time that the Mesozoic is known as the "age of dinosaurs."

As treated by geologists, sedimentary rocks are divided into "formations" which differ from each other in such features as mineral content, extent and thickness of individual layers, and kind of fossils. Each formation therefore reveals the geography, climate, fauna, and flora of its time. (See Fig. 7.)

Of the six formations prominently displayed in Zion National Park, the youngest is the Carmel limestone, 200 to 300 feet thick. Isolated remnants of this widespread formation appear at the top of East Temple, West Temple, the Altar of Sacrifice, and of many mesas on Kolob Terrace. East of the park boundary all of it is prominently exposed along the Zion-Mount Carmel highway. Its fossil shells indicate the date of deposition as at least 120,000,000 years ago. Most rocks younger than the Carmel have been worn away from the park areas but immediately east and north of the park boundary they appear as about 2800 feet of gypsum, coal-bearing standstones, and shales (Gray Cliffs) capped by 500 feet of limestone (Wasatch formation; Pink Cliffs). The youngest rocks are the lavas from volcanoes in Coalpits Wash, on Kolob Terrace, and outside the park on the summit lands of Markagunt Plateau.

Beneath the thin resistant Carmel limestone is the Navajo sandstone (White Cliffs), exceeding 2000 feet in thickness. From it have been carved the temples and towers, the cliffs and canyon walls that make Zion National Park unique among scenic regions. At the base of the cliffs of Navajo sandstone the Kayenta formation, in most places less than 200 feet thick, forms a shelving slope worn chiefly on thin maroon-colored sandstone. Beneath it is the Wingate sandstone which along the Virgin River is less than

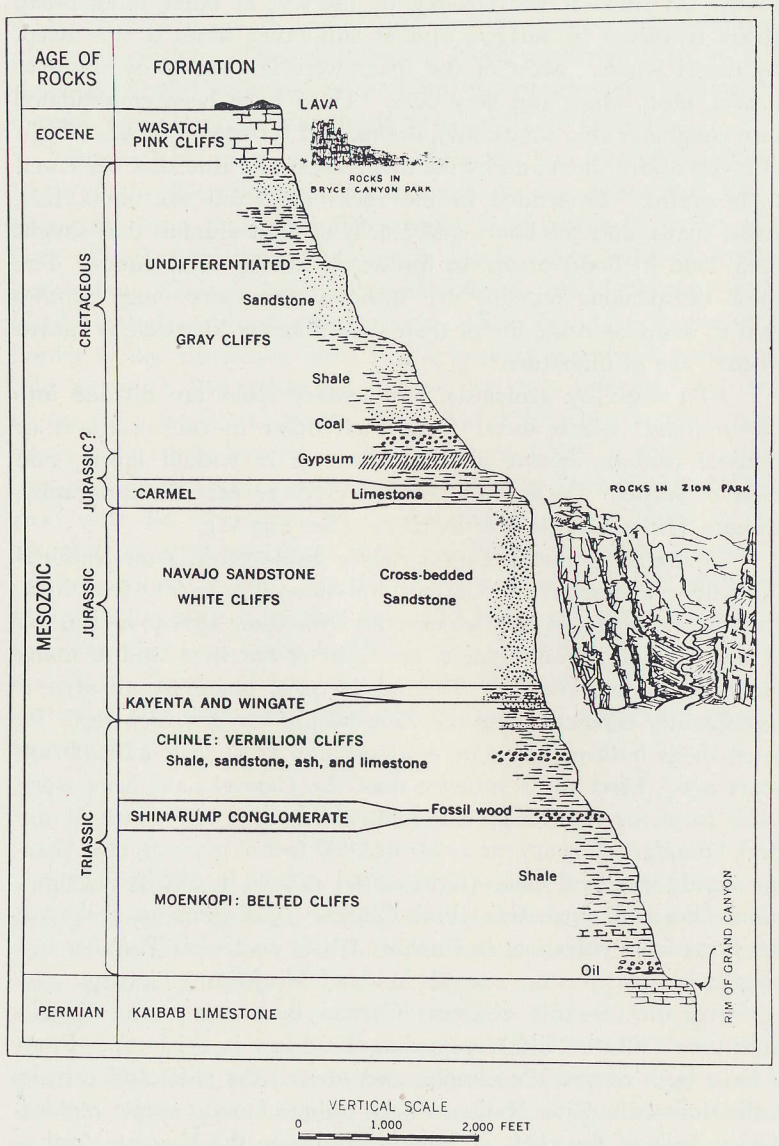

Figure 7. Generalized cross section of the geologic formations exposed in Zion Canyon and adjoining regions.

50 feet thick and thins to extinction in Zion Canyon. On slopes leading upward to the Watchman (Fig. 6), it stands as a low cliff but generally it is inconspicuous and in mapping has been combined with the Kayenta. Below the Wingate formation and not everywhere sharply separated from it is the Chinle (Chin-lee) formation (Vermilion Cliffs). With a thickness of more than 1000 feet it forms the brightly colored slopes and low cliffs below Springdale and the uppermost beds extend up Zion Canyon nearly four miles. The Chinle rests on the Shinarump (Shin-ar-ump) conglomerate, which though less than 100 feet thick, is a prominent cliff marker. It is the cap rock of sloping walls at the mouth of the Parunweap, and westward about Huber Wash and Coalpits Wash it forms the cape-like mesas on both sides of the Virgin River.

In turn below the Shinarump is the Moenkopi (Moen-kopi) formation (Chocolate Cliffs; Belted Cliffs), the oldest rocks exposed in Zion National Park. Along the Virgin River the whole of the Moenkopi (about 1800 feet) is displayed as a landscape of brightly colored bands. The highway through Virgin City, Grafton, and Rockville traverse successively higher beds until the top is reached at the mouth of the Parunuweap. Just outside the southwest border of the park the Kaibab limestone, the formation next older than the Moenkopi, appears in the Timpoweap canyon of the Virgin River and in Hurricane Cliffs. Extended southeastward it forms the top layer in the walls of Grand Canyon.

All the geologic formations represented in Zion National Park extend beyond its borders into the Kaiparowits and San Juan regions of southeastern Utah, the Navajo Country of northeastern Arizona, and westward into Nevada. In the park the Moenkopi, Shinarump, Chinle, Navajo, and Carmel formations are exceptionally well displayed; the Wingate and Kayenta are more fully developed elsewhere.

For visitors to the park who are interested in geologic history, the significant features of the formations exposed along trails and highways are outlined in the following paragraphs. (See Fig. 8.)

As shown in figures 2, 7, and 8 the formations lie one above another in orderly succession and their edges appear along cliffs

and canyon walls. The lowest (oldest) formation is exposed where the streams have cut the deepest valleys.

TRIASSIC FORMATIONS

As displayed in the Zion National Park region, the Triassic comprises two intricately carved brightly-colored steep slopes of shales, sandstones, limestones, and gypsum sharply separated by a gray cliff of resistant conglomerate. Beginning at the mouth of the Parunuweap, the lower slope (Moenkopi formation) broken midway up by a cliff and capped by a bench-making conglomerate (Shinarump), extends along Virgin River westward to the Hurricane escarpment. Above the Shinarump a precipitous slope of even more brilliantly colored rock (Chinle formation) rises to the walls of Kinesava Mountain and Smithsonian Butte, and continues along Virgin River past Springdale and into Zion Canyon beyond the Lodge as the lower pediment of such towers as West Temple, Bridge Mountain, the Patriarchs, Lady Mountain, and Castle Dome. Each of these three formations has characteristic features. (See Fig. 8.)

Moenkopi (Lower Triassic). — The Moenkopi formation comprises many thousands of thin layers of sandstone and shale, also beds of limestone and gypsum, most of them deposited in the sea, but some on coastal plains, and others along inland streams. The lower third of the formation consists of oil-bearing sandy limestones and shales overlain by several hundred feet of red, brown, and pink gypsum-bearing sandy shales capped by a few beds of fossiliferous limestone (Virgin limestone member) which forms a prominent cliff. The upper two thirds consists of strongly colored red sandy shales that include as a middle-division the remarkable group of gray, white, pink, and red soft gypsiferous beds known as the Shnabkaib (Schnab-kaib) shale member. Along the highway, the eroded edges of successively higher-lying beds are displayed as bright bands, a brilliant landscape in which the color bands outline clearly the minor erosion forms characteristic of the Moenkopi—flights of tiny steps in thin sandstone, slopes and mounds in soft gypsiferous shales, and low cliffs in the hardest beds—features prominent in themselves, but somewhat incon-

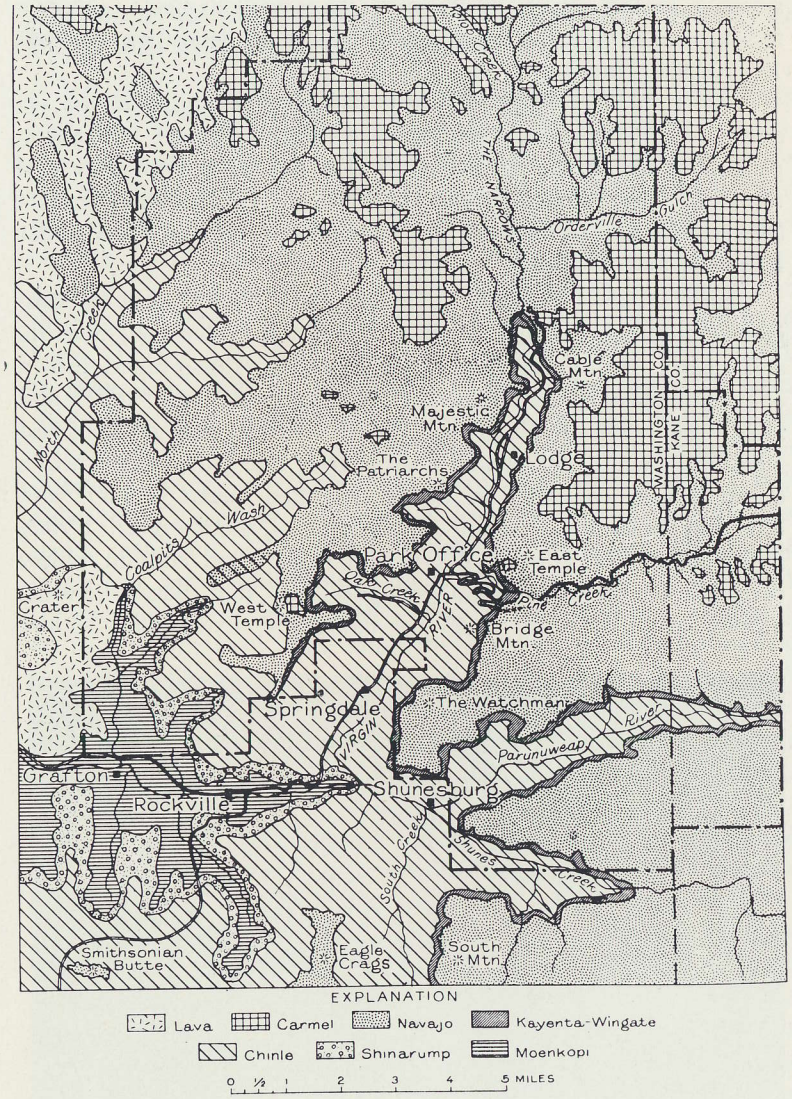

Figure 8. Geologic map of Zion National Park; a sketch showing the approximate location and extent of the Triassic and Jurassic formations. (To show their relations clearly the thicknesses of the Shinarump and the combined Wingate and Kayenta are much exaggerated.)

spicuous in this region of enormous steep-walled mesas. Marine fossils serve to date the beginning of Moenkopi deposition as about 175,000,000 years ago. (See Fig. 9.)

After the Moenkopi sediments had been deposited in the sea and along its borders, parts of them were removed by erosion producing an uneven surface on which the sands and gravels of the succeeding Shinarump were laid down. The irregular contact between the two formations (an unconformity) is well known near Rockville and Grafton.

SHINARUMP (UPPER (?) TRIASSIC). — The Shinarump conglomerate consists chiefly of white, gray, and brown conglomerate and coarse sandstone; thin, short lenses of fine-grained brown and red sandstone and mudstone; vari-colored sandy shale; and fossil wood. The dominant pebbles are well rounded, clouded and translucent white, yellow and gray quartz; red, gray, brown, white quartzite rock composed of firmly cemented quartz grains); and blue-gray limestone. About 10 per cent of them exceed 1 inch in diameter. Locally cavities in the fossil wood contain yellow carnotite or other uranium minerals and the spaces between pebbles are filled with iron and manganese oxides and copper

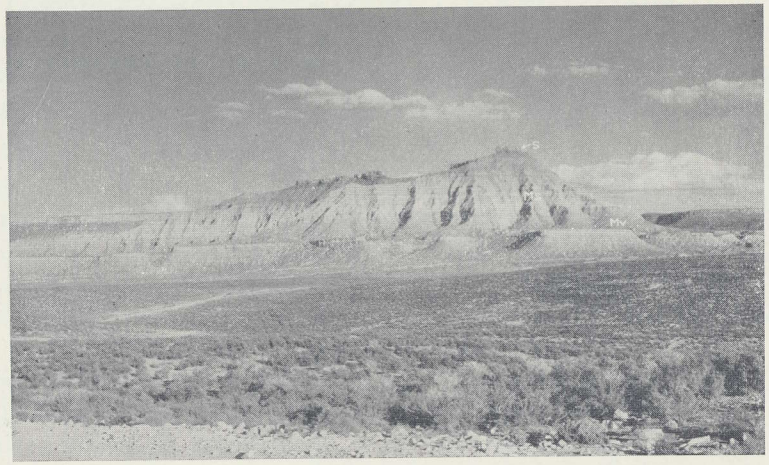

Figure 9. View of the Moenkopi as exposed along the highway north of Virgin City. Conspicuous parts of the formation are the cliff-making Virgin limestone member (Mv) and the white-banded Shnabkaib shale member (Ms). The cap rock (s) is Shinarump conglomerate.

sulphide in quantities sufficient to lure inexperienced prospectors. In the cliffs at Rockville the formation is typically displayed.

CHINLE (UPPER TRIASSIC).—Viewed as a whole the Chinle formation is a huge pile of coarse and fine sandstones, shales, gypsum, and limestone conglomerates, and is remarkable for its vividness and variety of color, for its unusual kinds of rocks, and for the abruptness of change in color, composition, texture, and bedding. The materials that constitute the formation were originally muds, silts, oozes, and volcanic ash deposited by streams and in shallow bodies of fresh water. Incorporated in them are fossil bones, tracks, fish, shells, and large amounts of petrified wood. In general the bedding is lenticular on both large and small scale. Some beds in the upper third of the formation may be traced for a mile, but most of them lose their individuality within short distances. Some are little more than thin, narrow lenses that appear and disappear within a few feet. Within the Chinle four zones, each with its characteristic bedding, color, and topographic expression, are readily distinguished. Two of them are especially conspicuous; the "big ledge" (Fig. 6) of resistant sandstone 80 to 100 feet thick that along the highway through Springdale divides the Chinle slopes into two parts; and below in the series of softer beds in which are buried forests of petrified trees. The beds that contain the petrified wood are marvelous assemblages of shales, soft sandstones, weathered volcanic ash, and many kinds of calcareous rocks colored with bands, streaks, and irregular blotches of yellow, lavender, purple, pink, lilac, ash-gray, and various shades of red, blue, and brown. They are the most richly colored beds in Utah. Their wide expanse, their brilliant coloring, and fantastic weathering make them an outstanding scenic feature, even in a region where most rocks are highly colored and eroded into picturesque forms. Some beds remain intact for several hundred feet but generally along the strike finely laminated sands or silts are replaced within a few feet by short thick lenses of sandstone conglomerate, gypsum, limestone conglomerate, or sheets of hard limestone, thin as paper. The colors likewise come and go along beds and across beds in a seemingly capricious manner. (See Fig. 10.)

JURASSIC (?) FORMATIONS

The Jurassic (?) formations (Middle Mesozoic) are of exceptional scenic interest. They make up the highest and most continuous cliffs of southern Utah and in them are cut the deepest canyons. Displayed as the Great White Cliffs, between the Paria and the Parunuweap, as the Block Mesas overlooking the Moccasin Terrace (north of Pipe Spring), and as the temples, domes, and lofty buttes of Zion National Park, they dominate the landscape from almost any viewpoint. Zion Canyon itself is essentially a slot sunk into Jurassic sandstone (Fig. 3.) Within the park three formations of probable Jurassic age are represented: the Wingate, overlain in turn by the Kayenta and the Navajo, and one of known Jurassic age, the Carmel. The higher beds in the Jurassic of Utah appear in fragmentary form along the northern park border and are fully developed along the Zion-Mt. Carmel highway. As displayed in the park, the Wingate, Kayenta, and Navajo formations (classed by geologists as the Glen Canyon group) differ in thickness and topographic importance from equivalent beds in eastern Utah and Arizona. Thus the Wingate elsewhere generally thick and prominent in cliffs, is here thin and hence inconspicuous. Likewise, particularly in distant views, the red Kayenta, rarely more than 200 feet thick, holds no well-

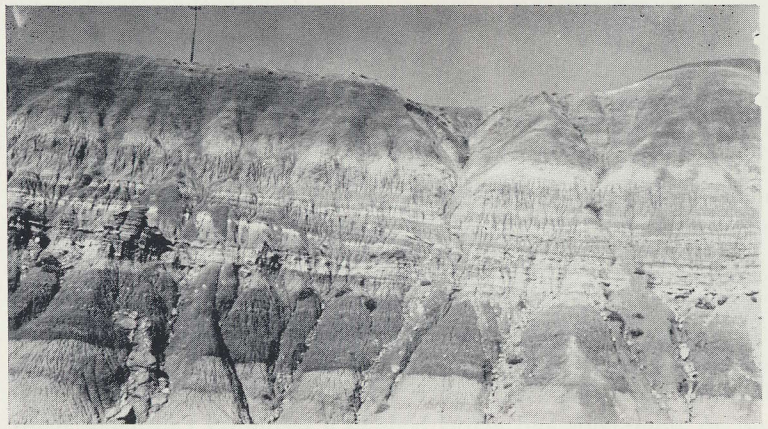

Figure 10. View of the lower part of the Chinle along the highway between Rockville and Springdale. Beds in this part of the formation contain much petrified wood.

marked place in the series of red beds of 3000 feet. On the other hand, the Navajo attains its fullest development With a maximum thickness exceeding 2000 feet it forms the canyon walls of the Virgin, the Parunuweap, Pine Creek, North Creek, La Verkin Creek, the towers of the park and such outlying masses as Eagle Crags and Smithsonion Butte. The Carmel formation, though relatively thin, is distinctive in form and composition and a topographic feature of wide extent. It constitutes the floor of Kolob terrace into which the great canyons of the park are incised and is the cap of the loftiest mesas.

Wingate (Lower Jurrasic ?). — In the park as elsewhere the Wingate is a strongly cross-bedded sandstone, white, tan, or red in color, and consists predominantly of clear rounded quartz grains weakly cemented with lime, mingled with iron. In large part it is an accumulation of wind blown sand. On cliffs and steep slopes the formation appears as a step, some 80 feet thick in middle Parunuweap Canyon and with decreasing thickness westward where it loses its individuality. Its characteristic features are shown in Kanab Canyon along the Zion-Grand Canyon highway.

Kayenta (Lower Jurassic ?). — Above the Wingate and without any great lapse of time the sediments that comprise the Kayenta Kay-en-ta) were deposited by ephemeral and intermittent streams. The formation is chiefly a series of dark red and purple, thin and thick-bedded, coarse and fine-grained sandstones that overlap, tail out, or end abruptly within short distances Quartz in rounded, well-sorted grains is the predominant mineral; the cement is chiefly calcite in intergrain spaces and iron in films tightly wrapped about the grains. Compared wth the formations above and below, the Kayenta is impervious. Throughout the park its top marks the position of springs.

Navajo (Middle Jurassic ?).—The Navajo is essentially a huge mass of remarkably homogeneous, fine-grained, friable, quartz sandstone held together by calcareous cement. Everywhere most of it, and in places all of it, is a single, massive, elaborately cross-bedded stratum. In the Zion National Park region, particularly where the Wingate and Kayenta are absent, its basal portion, 100 to 300 feet thick, consists of somewhat regularly bedded strata.

The top beds are also distinctive. They consist of sandy shale and massive sandstone that on weathering form secondary cliffs and mesa-like tops of isolated masses of the Navajo. Fully 98 per cent of the Navajo formation consists of rounded grains of translucent quartz, many of them frosted and some wind-etched. The grains are held together chiefly by lime, iron oxides, and clay-like substances, but the cement is weak and the rock therefore remarkably porous and friable. Big slabs on falling to the talus may crumble into dust, and seemingly solid boulders may crush under foot. Projecting ledges are precarious footholds. The iron is the coloring matter in the rock; hematite is chiefly responsible for the red colors, limonite for the yellow, and iron-bearing clay for the rare green tones. Where the iron cement is largely absent the rock may be nearly white. See Fig. 11.)

The outstanding feature of the Navajo is the bedding. Unlike most sedimentary rocks that over wide areas consist of horizontal layers superposed in orderly fashion, this sandstone is built of laminae disposed in all sorts of positions. Some laminae appear as groups of parallel straight lines, vertical, horizontal or oblique,

Figure 11. Checkerboard Mesa, one of many similar headlands along the Zion Mount Carmel Highway. Shows the cross-bedding and adjoining characteristic of the Navajo which forms the White Cliffs.

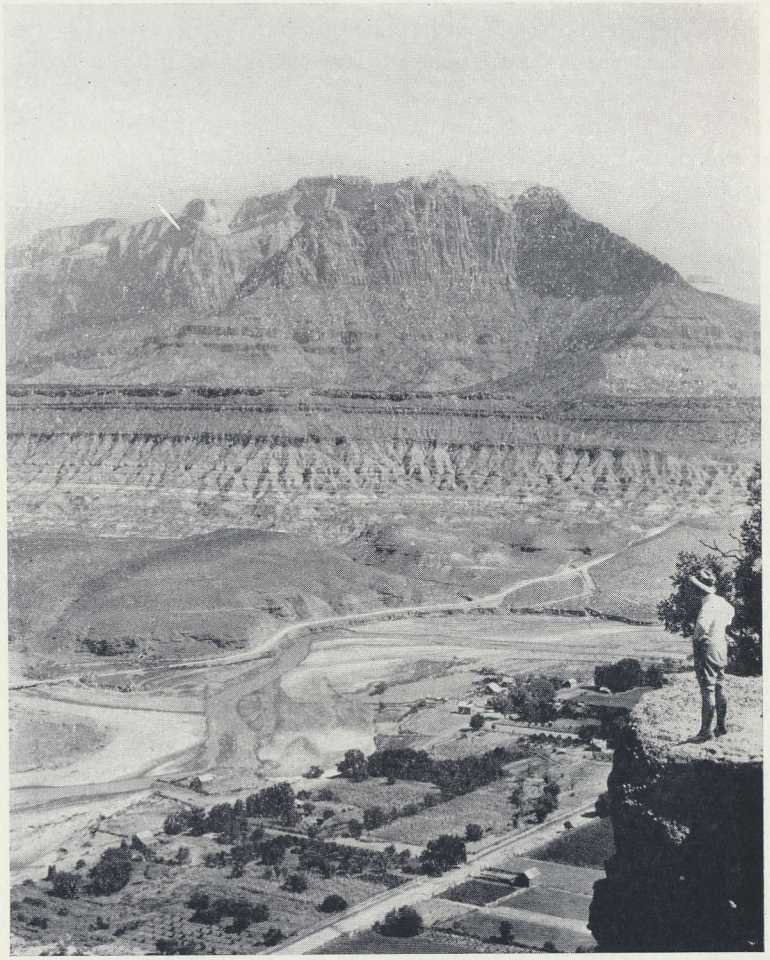

Figure 12. The towering West Temple as seen approaching Zion National Park from the southwest. Immediate foreground the pioneer village of Grafton, Utah, on the Virgin River. Center foreground Moenkopi formation, capped by Shinarump that forms bench (center), which is overlain by the lower Chinle. The heavy ledge in upper part of middle third of picture is the "big ledge" member of the Chinle. Talus slope at base of upper straight wall Kayenta and Wingate. Upper exposures all Navajo except round cap on top of West Temple which is Carmel. (Photo by Zion Picture Shop).

and are sharply truncated along inclined or horizontal planes. Others are curved, sweep through long arcs, and gradually decrease in curvature until they become tangent to those beneath. Series of parallel curves overlap or merge with series of different radii. Some are grouped as wedges. In places the laminae are wrinkled and squeezed into loops. Many sets of laminae retain their individuality for a few hundred feet, though commonly they extend tens of feet, some are measured in inches and are recognizabl only on weathered surfaces. The remarkable bedding (cross-bedding) of the Navajo, its composition, its fossil land shells and dinosaur tracks indicate that the sands that compose it were deposited on a land surface in an arid region and that the dominant agent of deposition was wind.

The unevenly worn surface at the top of the Navajo is a feature full of meaning; it marks the time when land in southwestern Utah was replaced by the sea; when desert sands were covered by silts laid down by waves and currents. As expressed by geologists, the wind and stream-made sediments constituting the Navajo are uncomfortably overlaid by the marine Carmel.

Carmel (Upper Jurassic).—The Carmel formation, 200 to 300 feet thick, is charasteristically hard compace limestone in groups of beds 1 to 4 feet thick, separated by groups of thinner, more sandy, limy beds. Its bedding and composition reveal its origin as silts deposited in a shallow sea. Abundant fossils fix its age. Within the park the Carmel is not readily accessible. It is exposed in road cuts near the east entrance.

VOLCANIC ROCKS

Lava.—The lava flows at Coalpits Wash, and along North Creek are outliers of more extensive sheets on Kolob Terrace and the Markagunt Plateau. Most of them may be traced to their feeding craters. All of them are composed of basalt in the form of dense rock, porous clinkers, bombs, and coarse-grained miscellaneous fragments. All the volcanic eruptions that produced the lavas are of recent geologic dates. The craters retain much of their original shape and the flows pass over the cliffs, across lands, and follow canyons that had their present forms before the eruptions took place.

THE ORIGIN OF ZION VALLEY

By

Russel K. Grater

Park Naturalist

To many visitors there is a marked similarity in shape between the sheer-walled gorge of Zion Canyon and the Yosemite Valley in Yosemite National Park, though the colors of the two areas are decidedly different. In both areas the canyon walls rise sharply from a flat valley floor, culminating in a series of high peaks and domes on the rim. So pronounced is this similarity in appearance that many people feel that their origins must be somewhat the same.

It is easy to show, however, that while glaciation was largely responsible for Yosemite Valley, no glaciers occurred at Zion. What appears to be "ice lines" on the walls of Zion Canyon are in reality only dune deposits of the Navajo formation, cross-sectioned by the cutting of the Virgin River and etched out through centuries of weathering. The sheer walls, so characteristic of

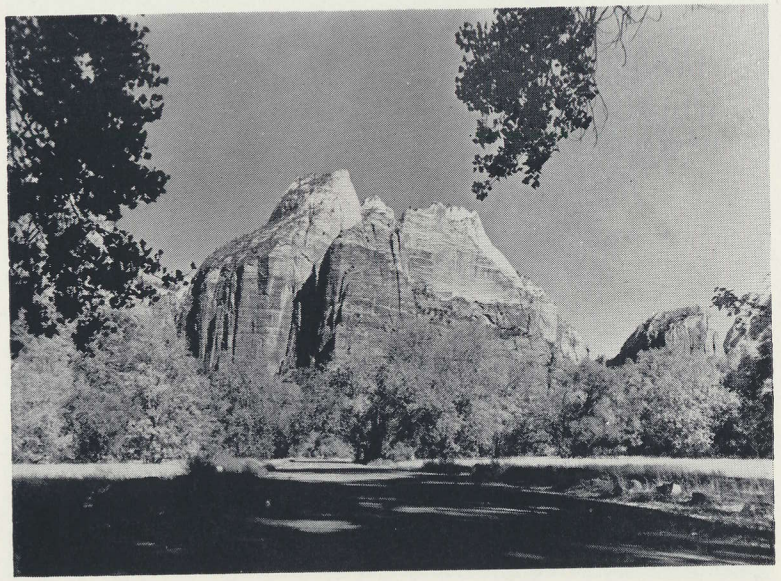

Fig. 13—Zion Valley near Mt. Majestic. The characteristic flatness of the valley floor is well illustrated in this sector.

glaciation, have been largely due to the extensive fracture system of the region, plus the action of natural arches created by the seeps at the base of the cliffs. Working together these two factors have aided in keeping the walls relatively vertical.

The origin of the flat valley floor of Zion brings to light one of the most interesting chapters in the history of the canyon. From field studies completed in 1943, the probable events leading up to the present-day valley can be reconstructed.

A few thousand years ago the Virgin River had cut down to the Springdale member of the Chinle formation in the vicinity of the Court of the Patriarchs and through it to the southward. Rising to the west towered the huge bulk of Sentinel Mountain. Now Sentinel Mountain, like the rest of the plateau, was sitting on a tilt to the eastward of aproximately 2 degrees. Running through the mountain itself was a series of fractures, one of them extending far to the northward through Phantom Valley and Wildcat Canyon. Quoting now from "Landslide in Zion Canyon, Zion National

Fig. 14—Sentinel Mountain. From its highly shattered face came the slide whose debris can be seen below.—Grater Photo.

Park, Utah (1)": "Then came a tremendous slide that blocked the entire canyon. From the formations involved it seems probable that water, fed into the fractures, filtered downward until the shale beds on top of the Springdale member were thoroughly saturated, creating a "greased skid" for the great mass of overlying rocks. As the slide came down into the canyon it fanned out, filling in the gorge from the present location of the Zion-Canyon Mount Carmel Road junction to the west side of the Court of the Patriarchs. The crest of the slide was directly oposite the Sentinel and shoved a great mass of debris high up on the slope beneath the Twin Brothers and Mount Spry. That the crest of the slide was at least 500 feet above the river-level is shown by the fact that the river was then around the 4,100-foot level, and the present high points of the slide on opposite sides of the river are 4,712 feet and 4,703 feet, respectively. Erosion has undoubtedly lowered the crest, although not to any great extent. The blocking of the river formed a large lake that filled the canyon probably back as far as the Narrows at the foot of the Mountain of Mystery. In this still water, silt and clay muds carried by the old Virgin River were dropped, forming extensive beds of clay underlain with oozy muck. In the meantime, the impounded waters finally began to pour over the top of the slide barrier. The lowest point along this barrier was on the east side of the canyon below the toe of the slide. Probably the initial erosion was rapid, as the waters had a tremendous fall and had only loose debris to move. It is believed that the maximum lake elevation was maintained for only a comparatively short time and so left no mark of its position. After this, the lowering of the lake level by removal of the slide debris was probably slower, allowing extensive deposition to continue in and around such still-water areas as Birch Creek and Emerald Pool canyons as well as behind the rock dam itself. The final draining of the lake and the exposure of the clay deposits was probably a relatively slow process, as the deeper the stream ate into the slide debris, the more its gradient was reduced and the slower it cut. This allowed for partial consolidation of the underlying clays in the lake fill, and their protection against rapid erosion by a heavy vegetation cover that came in over the valley floor. Today, at least 76 feet of this lake fill have been removed at its lower end, yet extensive deposits remain that are virtually untouched.

There has been much speculation as to how rapidly the slide debris has been removed and will be removed in the future. Some conception of this can be obtained by records kept since the park was established in 1918. Since that date there have been two major slides involving the old slide debris. Both slides, incidentally, occurred because the saturation by water of the shale beds overlying the Springdale member of the Chinle allowed the entire mass to move. No figures are available as to the amount of material that came down and blocked off the river in 1923, but the 1941 slide was estimated to have comprised at least 150,000 cubic yards of rock debris. Thus, in twenty years, the river has removed a great quantity of the old slide. Using this as a gauge, the rate of removal and erosion has been rapid, and at most only a few thousand years can have elapsed since the slide occurred."

The great valleys of Zion and Yosemite thus have one thing in common in their origins. In both instances the rivers were dammed up by rock debris, forming lakes which were finally filled with silt, creating the flat valley floors of today. In Yosemite this natural dam was the result of glacial action; in Zion it was due to a mammoth rock slide.

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